

HARECES Measurement of Magnetic Linear Dichroism

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- With the development of spin-based electronics and nanoscale manipulation of structure, tremendous efforts have been focused on fabricating and characterizing nanoscale devices. Since the spin transport occurs through the bulk of multi-layered nanostructures, techniques that are directly sensitive to the magnetic anisotropy within a specimen and its internal interfaces are of great interest, particularly those which operate at high spatial resolution.

- Magnetic Linear Dichroism (MLD) is an often-used method to study magnetism through the analysis of changes in X-ray Absorption Near Edge Structure (XANES) measured at synchrotron radiation sources. In an electron scattering experiment, a similar spectroscopy, namely electron Energy-Loss Near-Edge Structure (ELNES), can be also employed to study MLD. In this case, we make use of the fact that the perturbing electric field of an incident electron probe is longitudinally polarized in the direction parallel to the momentum transfer and thus can be used to probe the electronic and magnetic structure of a material.

- The interest in exploring MLD measurements using an electron microscope arises from this added advantage: in these instruments the spatial resolution is far superior to that of synchrotron sources.

- MLD in an electron microscope is realized at ANL by using the high angular resolution electron channeling electron spectroscopy (HARECES) facilities in the ANL EM Center. In our initial work we have verified the ability of our methods to measure MLD by studying the changes in core-loss spectra acquired from material in different magnetic states. As in XANES, we determine MLD by measuring the intensity of p → d transitions in L-shell spectra of transition metals.

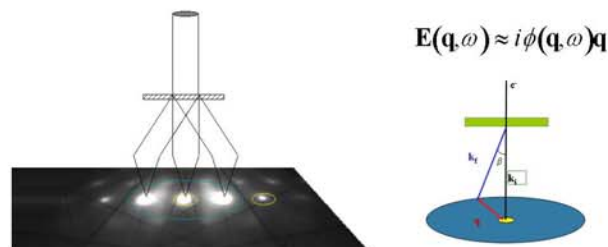


Figure 1. Traditional EELS measurements are performed using large apertures and poor angular resolution (~ 10 mrad). In HARECES we employ computationally-mediated control of the electron microscope which allows spectroscopic measurements at angular resolutions as small as 0.05 mrad.

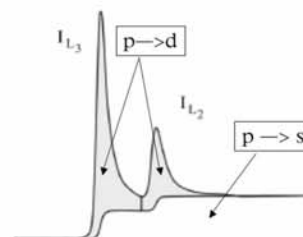


Figure 2. L-shell spectra are made up of 2 components: p → s and p → d transitions. The p → d components are those which are sensitive to the magnetic state of the material.

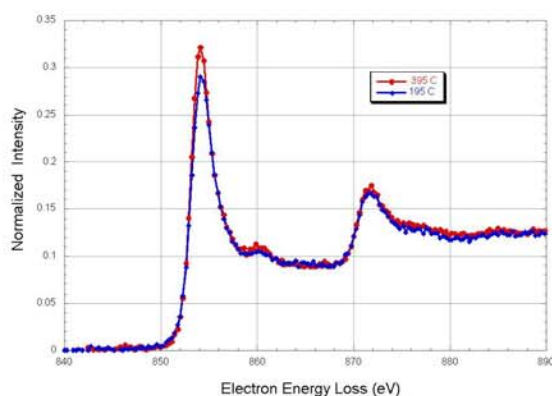


Figure 3. Nickel L-shell spectra recorded above (red) and below (blue) the Curie temperature to verify that HARECES based MLD is sensitive to the magnetic state.

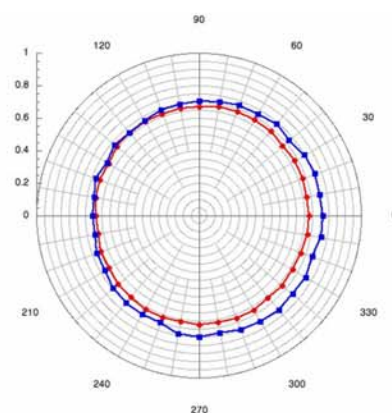


Figure 4. Orientation dependence of the Ni L-shell intensity above (red) and below (blue) the Curie temperature. The change from a nearly angularly isotropic (red) to an anisotropic (blue) distribution can be interpreted as the formation of an oriented magnetic domain in the plane of the specimen.

Determining the optimum conditions for measuring MLD using HARECES will be the focus of near term studies in order that we can establish this technique as a routine method for high spatial resolution magnetic measurements.